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SPECIFICATION

Title of the Invention

METHOD FOR EVALUATING REPRODUCIBILITY OF TONING SAMPLE BYCCM

Technical field

The present invention relates to a method for evaluating the reproducibility of colors derived from a sample color producing process (coloring process) regarding a 2 or more different color samples having different coloring agent recipes produced by CCM toning or visual toning by which colors are adapted to the target color, using the CCM techniques.

Background techniques

In a toning process for adapting colors to a target color presented by the instructions of customers is usually performed via production of around 3 different color samples in the case of CCM toning, or via production of an around 3 to 5 different colors samples in the case of visual toning. Regarding precision on CCM by which simulated color is matched to the target color, when CCM correction toning is effected, the color difference is gradually decreased necessarily and, finally, the target sample can be almost reproduced. However, in a coloring process in which a colored product is obtained based on the color mixing determined by CCM toning or visual toning, there arises a problem

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on the reproducibility in a coloring step due to the influence of the measuring error or the use of poor color reproducibility agents or the like. When the reproducibility in a coloring step including the measuring error or the like is deteriorated, the color difference is not converged beyond that reproducibility. When colors of a colored product (final sample numbered product) produced according to CCM or visual color matching are not consistent with the target color, there is a problem on the reproducibility in many cases.

Previously, when the reproducibility of colors in a coloring step is examined, for example, when the reproducibility is examined on sample No. 3 among a 5 samples group, the sample color has to be produced a few times based on the relevant color mixing. In addition, when there is no problem regarding the reproducibility of sample No.3, the similar examination has to be further performed on other sample No. product for which kinds of coloring agents are the same but their mixing rate is different.

However, the production of a sample for confirmation of the reproducibility in the toning work is laborious in the sample production and is actually impossible in respect of the efficiency. For that reason, if the results of the actually measured color difference of a sample product produced in a toning process such as CCM toning or visual toning as well as the reproducibility are rapidly and simultaneously displayed

on a computer screen, determination whether toning is to be continued or toning should be stopped can be done earlier and, at the same time, materials for determinating the strategy can be obtained, being advantageous. In addition, when there is a problem on the reproducibility of the development of a particular coloring agent, if what coloring agent is mixed to what extent is known, the cause can be investigated and, at the same time, the production efficiency can be enhanced, being advantageous.

Therefore, an object of the present invention is to provide a method for evaluating the reproducibility of a toning sample, which can rapidly and simply perform determination whether the toning work is to be continued or not, by displaying the actually measured color difference of a sample product produced in a toning process such as CCM toning and visual toning and the reproducibility. Another object of the present invention is to provide a method for presuming a component such as a coloring agent mixed into a toning sample, when the abnormal sample is perceived in the method for evaluating the reproducibility of the sample, and a method for presuming its mixed amount.

SUMMARY OF THE INVENTION

Under such the circumstances, the present inventors studied intensively and, as a result, we found that (1) under the conditions that there are 2 or more sample groups produced in

a CCM toning or visual toning process by which colors are adapted to the target colors and respective components such as a coloring agent defining the sample color are registered in a CCM system, spectral reflectance RPR-n can be calculated beyond simulation corresponding to each colors mixing (each toning sample), and difference between the RPR-n and the actually measured spectral reflectance RST-n at the same -n becomes a simulation error of CCM and, usually, since toning is performed mainly by fine correction to the target colors in a narrow range in a color space, the CCM simulation error in a toning sample group becomes constant and, therefore, when the difference between RST-n and RPR-n is not constant, it can be determined that the reproducibility of colors derived from a coloring step (sample production) is deteriorated, (2) when an abnormal sample is observed in the method for evaluating the reproducibility of a toning sample, the difference $\Delta R' - b$ of the sample obtained from a particular equation is determined, and compared with the difference $\Delta R' - m$ based on a toning sample derived from the CCM simulation by which colors are adapted to the target colors and, whereby, a component such as a coloring agent which has mixed into the sample can be presumed and its mixed amount can be presumed, which resulted in completion of the present invention.

That is, the present invention (1) provides a method for evaluating the reproducibility of a toning sample by CCM, which

comprises, under the conditions that there are 2 or more samples produced in a CCM toning or visual toning process by which colors are adapted to a target color and respective components such as a coloring agent defining the sample color are registered in a CCM system, evaluating the reproducibility of the samples based on the difference $\Delta R-n$ (n denotes a sample number) between spectral reflectance $RST-n$ obtained by actually measuring the respective sample and spectral reflectance $RPR-n$ obtained by the CCM simulation corresponding to the coloring agent recipe for the sample at the same n .

In addition, the present invention (2) provides a method for evaluating the reproducibility of a toning sample by CCM, which comprises, under the conditions that there are 2 or more samples produced in a CCM toning or visual toning process by which colors are adapted to a target color and respective components such as a coloring agent defining the sample color are registered in a CCM system, evaluating the reproducibility of the samples based on the difference $\Delta T-n$ (n denotes a sample number) between spectral transmittance $TST-n$ obtained by actually measuring the respective sample and spectral transmittance $TPR-n$ obtained by the CCM simulation corresponding to coloring agent recipes for the sample color at the same n .

In addition, the present invention (3) provides a method for evaluating the reproducibility of a toning sample by CCM according to the above (1), wherein evaluation of the

reproducibility of the samples is performed from the difference between either of n for $\Delta R-n$, or an average for $\Delta R-n$ and the $\Delta R-n$.

In addition, the present invention (4) provides a method for evaluating the reproducibility of a toning sample by CCM according to the above (2), wherein evaluation of the reproducibility of the samples is performed from the difference between either of n for $\Delta T-n$, or an average for $\Delta T-n$ and the $\Delta T-n$.

In addition, the present invention (5) provides a method for evaluating the reproducibility of a toning sample by CCM according to any one of the above (1)-(4), wherein evaluation is performed based on the difference of color specification value such as $\Delta L^*a^*b^*$ corresponding to the difference of spectral reflectance $\Delta R-n$ or the difference of spectral transmittance $\Delta T-n$, statistical value such as maximum, minimum and standard deviation of the difference of color specification value and the color difference as well as the color difference calculated from the statistical value.

In addition, the present invention (6) provides a method for evaluating the reproducibility of a toning sample by CCM, which comprises incorporating the method for evaluating the reproducibility of a toning sample as defined in the above (5) into a CCM software and calculating the coloring agent recipes of the samples by CCM toning and, thereby, the reproducibility

can be confirmed.

In addition, the present invention (7) provides a method for evaluating a toning sample, which comprises, in a method for evaluating the reproducibility of a toning sample by CCM system, under the conditions that there are 2 or more samples produced in a CCM toning or visual toning process by which colors are adapted to a target color and respective components such as a coloring agent defining the sample color are registered in a CCM system, based on the difference $\Delta R-n$ (n denotes a sample number) between spectral reflectance $RST-n$ obtained by actually measuring the respective samples and spectral reflectance $RPR-n$ obtained by the CCM simulation corresponding to the coloring agent recipes for the samples at the same n , extracting a sample indicating the abnormal value $\Delta R-b$ (b means bad) different from others among $\Delta R-n$ of the samples, and presuming components such as a coloring agent mixed in the sample indicating the abnormal value or presuming its mixed amount via the following respective steps;

(1) a step of calculating either of n except for b among the $\Delta R-n$ or an average of $\Delta R-n$ except for b , wherein actually measured spectral reflectance of a sample indicating the abnormal value is $RST-b$ and spectral reflectance obtained by CCM simulation corresponding to the coloring agent recipe is $RPR-b$; (2) a step of adding a calculated value obtained in the above (1) to spectral reflectance $RPR-b$ by CCM system to obtain

corrected provisional true value $RST' -b$; (3) a step of determining the difference $\Delta R' -b$ between the provisional true value $RST' -b$ and actually measured spectral reflectance $RST-b$; (4) a step of, using (actually measured spectral reflectance $RST-b - \Delta R-ave$) value as a corrected target color, obtaining spectral reflectance $RPR-m$ obtained by simulation from the existing CCM data for toning to the corrected target color, and obtaining the difference $\Delta R-m$ between the simulated spectral reflectance $RPR-m$ and the simulated spectral reflectance $RPR-b$ by CCM system; (5) a step of determining the difference $\Delta R-m$ so that the difference between the $\Delta R' -b$ and the difference $\Delta R-m$ becomes minimum.

In addition, the present invention (8) provides a method for evaluating a toning sample, wherein said method is performed using spectral transmittance $\Delta T-n$ instead of spectral reflectance $\Delta R-n$ in the invention described in the above (7) and, in addition, the present invention (9) provides the method for evaluating a toning sample according to the above (7) or (8), wherein the difference of color specification value or color difference obtained based on the difference $\Delta R-n$ is used in place of the above difference $\Delta R-n$, or the difference of color specification value or color difference obtained based on the difference $\Delta T-n$ is used in place of the $\Delta T-n$.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a view showing the relationship between spectral

reflectance RST-n obtained by actual measurement in the samples and simulated spectral reflectance RPR-n obtained by CCM system(left side) and the difference ΔR -n thereof (right side), Fig.2 is a view for explaining the case where $n=b$ in Fig.1, Fig.3 is a view showing the difference (ΔR -n) curve between actually measured spectral reflectance of a toning sample in Example 1 and simulated spectral reflectance by CCM system, Fig.4 is a view showing the difference curve for the difference between actually measured spectral reflectance of a toning sample and simulated spectral reflectance by CCM system, Fig.5 is a view showing the difference (ΔR -n) curve between actually measured spectral reflectance of other toning sample and simulated spectral reflectance by CCM system, Fig.6 is a view showing the difference curve for the difference between actually measured spectral reflectance of other toning sample and simulated spectral reflectance by CCM system, Fig.7 is a view showing one example of a computer screen displaying the reproducibility, Fig.8 is a view showing another example of a computer screen displaying the reproducibility, Fig. 9 is a view showing the difference (ΔR -n) curve for samples in Example 2, Fig. 10 is a view showing the relationship between $\Delta R'$ -b, $\Delta R''$ -b, ΔR -b and ΔR -actual, Fig. 11 is a view showing the difference of the difference ($\Delta R'$ -m- $\Delta R'$ -b), and Fig. 12 is a view showing the difference of the difference ($\Delta R'$ -L- $\Delta R'$ -b) in Comparative Example, respectively.

The best mode for carrying out the Invention

A method for evaluating the reproducibility which is the first invention is performed under the conditions that there are 2 or more samples produced in a CCM toning or visual toning process by which colors are adapted to the target color and respective components such as a coloring agent defining the sample color are registered in a CCM system .

In the present invention, toning such as CCM toning and visual toning is not particularly limited but includes various tonings such as new product toning by which colors are adapted to the target color presented by customers and correction toning of a lot product in production section. Performance of these tonings by CCM is CCM toning and performance by human visual sense is visual toning. In addition, the form of the target is not particularly limited as long as a product is a color agent mixed series colored product, but includes printed products, plastic molded articles, coated products and dyed products.

Explaining referring to CCM toning, for example, in the case of new product toning, spectral reflectance or spectral transmittance is obtained by actually measuring the target sample (since the similar effects or advantages are exerted in spectral reflectance or spectral transmittance in the present invention, explanation is effected using spectral reflectance

hereinafter for convenience), the color agent recipe of the sample conforming to the spectral reflectance is obtained by CCM simulation. That is, a sample product is produced based on optical data (absorption coefficient and scattering coefficient) of a coloring agent which is registered in CCM, corrected products are successively produced based on spectral reflectance of an already toned product (n =last time product) and, finally, a sample product conforming to the target color, that is, spectral reflectance obtained by actually measuring the target sample is obtained. The number of sample products is around 2-3 in the case of a new product toning. Visual toning is carried out, for example, from production of the first sample to a final sample produced conforming to the target sample based on human visual sense. The number of such sample is around 3 - 5 in the case of a new produce toning.

Respective coloring agent recipe is present in each sample. Coloring agent recipe is determined, for example, by a ratio of blending components such as a substrate and a coloring agent. Therefore, actually measured spectral reflectance of each sample, that is, each of sample 1 ($n=1$), sample 2 ($n=2$), sample 3 ($n=3$) . . . and sample n ($n=n$) is naturally different. For this reason, even when spectral reflectance RST-ns obtained for every sample are compared, the reproducibility can not be compared. In addition, n means a sample number.

In the present invention, under the conditions that the

equation (2).

$$R=1+(K/S)-((K/S)^2+2(K/S))^{1/2} \quad (2)$$

wherein, R denotes spectral reflectance of a subject to be toned, K denotes an absorption coefficient of a coloring agent, and S denotes a scattering coefficient.

In the case of the 1 constant method of Kubelka-Munk theory, a predetermined amount of each color (for example, red ink and blue ink) is weighed, spectral reflectance of a colored product having each color is measured, and a K/S function of a coloring agent, that is, F_n is registered in advance from the equation (1). F_n is indicated by the equation (3).

$$F_n=((K/S)_n-(K/S)_0)/C_n \quad (3)$$

wherein, $(K/S)_n$ denotes a K/S value obtained by the equation (1) from spectral reflectance of a colored product, $(K/S)_0$ denotes a K/S value of a product to be colored (for example, paper), C_n denotes wt% of a coloring agent, F_n denotes a K/S value harbored by a coloring agent itself per color unit wt%, and n denotes a color name.

When a plurality of coloring agents are mixed and the mixed color affords a colored product, a $(K/S)_{\text{mix}}$ value is calculated according to the equation (4).

$$(K/S)_{\text{mix}}=F_1C_1+\cdots+F_nC_n+(K/S)_0 \quad (4)$$

Since coloring agent recipe of a toning product is known, C_n in the equation (4) is known and, since F_n and $(K/S)_0$ are registered in a CCM system in advance, $(K/S)_{\text{mix}}$ of a toning

product is obtained. $(K/S)_{\text{mix}}$ is substituted for K/S in the equation (2), and simulated spectral reflectance RPR-n is obtained by CCM system.

In the case of the 2 constants method of Kubelka-Munk theory, the equation (5) of Duncan is applied in a mixed color.

$$(K/S)_{\text{mix}} = (K_1 C_1 + \dots + K_n C_n + K_0) / (S_1 C_1 + \dots + S_n C_n + S_0) \quad (5)$$

wherein, K_n denotes an absorption coefficient of each coloring agent, S_n denotes a scattering coefficient, C_n denotes wt%, K_0 denotes an absorption coefficient of a product to be colored (for example, resin), and S_0 denotes its scattering coefficient.

The equation (5) is developed into the equation (6) using the particular pigment such as white a as a reference and other colors as a value relative to the reference.

$$(K/S)_{\text{mix}} = \sum (K_n/S_n) (S_n/S_a) C_n + \dots + (K_0/S_0) (S_0/S_a) / (\sum (S_n/S_a) C_n + \dots + S_0/S_a) \quad (6)$$

wherein, K_n/S_n denotes a K/S value obtained from the equation (1) by measuring spectral reflectance of product that is colored by each coloring agent, K_0/S_0 denotes a K/S value obtained from the equation (1) by measuring a product to be colored (for example, resin), S_n/S_a denotes a relative scattering coefficient of each coloring agent relative to white a, and S_0/S_a denotes a relative scattering coefficient of a product to be colored relative to white a. These values are registered in a CCM system in advance.

Since coloring agent recipe of a toning product is known,

C_n in the equation (6) is known and, since others are registered in a CCM system as described above, (K/S)_{mix} of a toning product is obtained. And, (K/S)_{mix} is substituted for K/S in the equation (2) and simulated spectral reflectance RPR-n is obtained by CCM system.

When a subject to be toned is transparent, the theoretical equation (7) of Lambert Beer is used.

$$D = -\text{Log}T \quad (7)$$

A predetermined amount of each coloring agent is weighed, spectral transmittance of a colored product is measured at that color, and a D function of each coloring agent, that is, D_n is registered in advance from the equation (7). The D value (D_n) harbored by a coloring agent itself per color unit wt% is represented by the equation (8).

$$D_n = (-\text{Log}T_n + \text{Log}T_0) / C_n \quad (8)$$

wherein, T_n denotes spectral transmittance of a colored product of each coloring agent, T₀ denotes spectral transmittance of a product to be colored (for example, resin), and n denotes a color name.

A plurality of coloring agents are mixed, and a D value of a colored product with the mixed coloring agents is calculated by the equation (9).

$$D_{\text{mix}} = D_1 C_1 + \dots + D_n C_n + D_0 \quad (9)$$

Since coloring agent recipe of a toning product is known, C_n in the equation (9) is known and, since D_n is registered in

a CCM system in advance, D_{mix} of a toning product is obtained. D_{mix} is substituted for D in the equation (7), and simulated spectral transmittance $TPR-n$ is obtained by the CCM system.

The aforementioned 1 constant method of Kubelka-Munk theory, 2 constants method of Kubelka-Munk theory and Lambert Beer method are techniques for CCM simulation, and one example of the procedure obtaining simulated spectral reflectance $RPR-n$ and simulated spectral transmittance $TPR-n$ by the CCM system.

In the method for evaluating the reproducibility of the present invention, evaluation of the reproducibility of the samples is performed based on the difference $\Delta R-n$ between spectral reflectance $RST-n$ obtained by actually measuring the each sample color and simulated spectral reflectance $RPR-n$ corresponding to coloring agent recipe for the sample color at the same n , or the difference $\Delta T-n$ between spectral transmittance $TST-n$ and spectral transmittance $TPR-n$ at the same n . The difference between $RST-n$ and $RPR-n$ at the same- n denotes CCM simulation error. Usually, since toning is performed mainly by fine correction to the target color in a narrow range in a color space, CCM simulation error in a toning sample may be considered to be constant. For that reason, the differences between $RST-n$ and corresponding $RPR-n$ are compared, and the reproducibility of colors is determined.

According to the present invention, the difference may be, in addition to the foregoing, the difference between either

of n for $\Delta R-n$, an average for $\Delta R-n$ or and the $\Delta R-n$, or the difference between either of n for $\Delta T-n$, or an average for $\Delta T-n$ and the $\Delta T-n$ and, further, the evaluation of the reproducibility may be performed based on the difference of color specification value such as $\Delta L^*a^*b^*$ corresponding to the difference of spectral reflectance $\Delta R-n$ or the difference of spectral transmittance $\Delta T-n$ and the color difference, or statistical values such as maximum, minimum and standard deviation of the difference of color specification value such as $\Delta L^*a^*b^*$, and the color difference calculated from the statistical values. As a method for comparing the differences, there are a method of displaying the difference curves at upper and lower sides or left and right sides, a method of displaying by overlaying the difference curves and a method of displaying the difference of the difference of spectral reflectance.

In the method for evaluating the reproducibility of the present invention, the aforementioned method for evaluating the reproducibility of a toning sample is incorporated into a CCM software and coloring agent recipe of the sample by CCM toning is calculated by CCM system and, thereby, the reproducibility can be confirmed by a computer screen of a CCM system and, at the same time, whether toning work is to be continued or not can be determined by this display of the reproducibility. For example, when (maximum-minimum) for the difference of color specification value indicated by the

aforementioned $\Delta L^*a^*b^*$ for evaluating the reproducibility obtained from samples is compared with the actually measured the difference of color specification value between the target sample and a toning last time product, usually dividing into L^* and a^*b^* of $L^*a^*b^*$ color system displayed in a color space, L^* is displayed in an ordinate axis having a midpoint of an actually measured point for the target sample and a^*b^* is displayed in a circular graph having a midpoint of an actually measured point for the target sample on a computer screen. Since this display indicates $\Delta L^*a^*b^*$ for a toning last time product represented by plotting in a positional relationship with the target color, when actually measured plotting for a toning last time product is in a range of the aforementioned (maximum-minimum) for $\Delta L^*a^*b^*$ for evaluating the reproducibility, it can be determined that further correction is impossible and toning should be stopped. In addition, when the last time plotting is outside the aforementioned (maximum-minimum) range, it can be determined that correction is still possible and toning should be continued. The last time product refers to an immediate prior product upon toning work.

The method for evaluating a toning sample which is the second invention will be explained referring to Fig. 1 and Fig. 2. Fig. 1 shows the relationship between spectral reflectance R_{ST-n} obtained by actual measuring and simulated spectral reflectance R_{PR-n} obtained by CCM system (left side) and its difference

chroma color or dark color at a small amount of titanium oxide, the difference is not constant in some cases. However, in this case, it is preferable that spectral reflectance of the sample and coloring agent recipes near to these are input in advance and the predicted precision is enhanced.

A (2) step is a step of adding a calculated value obtained in the aforementioned (1) step to simulated spectral reflectance RPR-b by CCM system to obtain corrected provisional true value RST' -b as shown in following equation (10).

$$\text{Provisional true value RST}' -b = \text{RPR} - b + \Delta R - \text{ave} \quad (10)$$

wherein, $\Delta R - \text{ave} = 1/n \sum (\text{RST} - n - \text{RPR} - n)$, provided that b is excluded.

That is, provisional true value RST' -b is provisional spectral reflectance in the case where a n=b sample is produced without error. A (3) step is a step of determining the difference $\Delta R' - b$ between provisional true value RST' -b and actually measured spectral reflectance RST-b as shown in the following equation (11).

$$\Delta R' - b = \text{RST}' - b - \text{RST} - b \quad (11)$$

An extent of abnormality can be confirmed by this error $\Delta R' - b$ and from which coloring agent this error is derived can be also presumed by the following method. In addition, when the above (10) is substituted for RST' -b in the equation (11),

$$\Delta R' - b = \text{RPR} - b - (\text{RST} - b - \Delta R - \text{ave}) \quad (12)$$

is obtained, and this may be used as a standard equation

for determining an abnormal coloring agent. Thereafter, $\Delta R'$ -b represented by the equation (12) is also referred to as $\Delta R'$ -b.

A step (4) is a step of, using (actually measured spectral reflectance $RST-b - \Delta R-ave$) value as a corrected target color, obtaining spectral reflectance $RPR-m$ obtained by simulation from the existing CCM data for toning to the target color, and obtaining the difference $\Delta R-m$ between the simulated spectral reflectance $RPR-m$ and the spectral reflectance $RPR-b$ by CCM system. $RPR-m$ calculated from CCM data is obtained by inputting components such as a coloring agent in a computer in advance, and is output successively in the order of nearer to the target color. And, a step (5) is a step of determining the difference $\Delta R-m$ so that the difference between the $\Delta R'$ -b and the difference $\Delta R-m$ becomes minimum. From this, a coloring agent mixed in a sample indicating the abnormal value can be presumed and its mixed amount can be presumed. When actually measured spectral reflectance $RST-b$ as it is used as a target color, since the difference error between actually measured spectral reflectance and simulated spectral reflectance is existed, precise determination can not be done.

In a (4) step, $RST-b$ is used as a target color, spectral reflectance $RPR-m$ is obtained by simulation from the existing CCM data for toning to the target color, and the difference $\Delta R-m$ between the spectral reflectance $RPR-m$ and $RST'-b$ may

be obtained. When the cause for abnormality is due to a decreased amount of the particular coloring agent, amounts of coloring agents other than the particular coloring agent are increased and, when the cause for abnormality is due to an increased amount of the particular coloring agent, amounts of coloring agents other than the particular coloring agent are decreased.

In the aforementioned method for evaluating a toning sample, the difference $\Delta T-n$ may be used in place of the aforementioned difference $\Delta R-n$ and, in this case, spectral transmittance is used in place of spectral reflectance. In addition, even when the difference of color specification value or color difference obtained based on the difference $\Delta R-n$ is used in place of the aforementioned difference $\Delta R-n$, or even when the difference of color specification value or color difference obtained based on the difference $\Delta T-n$ is used in place of the aforementioned $\Delta T-n$, the similar results to those of the aforementioned method for evaluating toning samples can be obtained.

(Examples)

The following Examples further illustrate the present invention in more detail. For CCM simulation, the 2 constants method of Kubelka-Munk theory was used.

Examples 1

(Case I; case where a dispersion-processed coloring agent is used)

3 toning samples were reproduced for the target color. Samples

were produced by kneading a vinyl chloride resin composition (PVC resin compound) and dispersion-processed DA type coloring agent for PVC (manufactured by Dainichi-seika color & chemical MFG., Co., LTD.) at a kneading rate shown in Table 1 (unit is 'gram'). Kneading was performed at a temperature of about 170°C for 2 minutes using two heating rollers. After kneading, the predetermined molding processing was performed to obtain 3 kinds of samples.

Table 1

		1st Time (n=1)	2nd Time (n=2)	3rd Time (n=3)
PVC resin compound		1 0 0	1 0 0	1 0 0
Coloring agent	DA P4050 (White)	0. 8	0. 7 5	0. 7 5
	DA P4710 (Black)	0. 0 4	0. 0 4 5	0. 0 4 5
	DA P4420 (Yellow)	0. 1 0	0. 1 0	0. 1 1
	DA P4620 (Blue)	0. 0 6	0. 0 6	0. 0 5 5

The difference ΔR -n between actually measured reflectance RST-n and simulated reflectance RPR-n for a toning sample according to the above formulation is shown in Table 2. The difference curves of spectral reflectance regarding to ΔR -n in Table 2 is shown in Fig. 3, and the difference curves of spectral reflectance regarding to $(\Delta R2 - \Delta R1)$ and $(\Delta R3 - \Delta R1)$ are shown in Fig. 4. A transverse axis in Fig. 3 and Fig. 4 indicates wavelength, and an ordinate axis indicates the

difference in spectral reflectance, respectively. For CCM simulation, 'Colorcom CCM System' (manufactured by Dainichi-seika color & chemical MFG., Co., LTD.) was used, and spectral reflectance was obtained in a wavelength range of 400 to 700 nm.

Table 2

	RST-1	RST-2	RST-3	RPR-1	RPR-2	RPR-3	$\Delta R-1$	$\Delta R-2$	$\Delta R-3$
400nm	0.1370	0.1294	0.1247	0.1383	0.1302	0.1257	-0.0013	-0.0018	-0.0010
410nm	0.1351	0.1254	0.1224	0.1363	0.1282	0.1233	-0.0012	-0.0018	-0.0009
420nm	0.1331	0.1244	0.1201	0.1342	0.1262	0.1209	-0.0011	-0.0018	-0.0008
430nm	0.1311	0.1243	0.1199	0.1342	0.1261	0.1208	-0.0011	-0.0018	-0.0009
440nm	0.1373	0.1282	0.1235	0.1385	0.1299	0.1245	-0.0012	-0.0017	-0.0008
450nm	0.1433	0.1337	0.1291	0.1445	0.1357	0.1301	-0.0013	-0.0020	-0.0010
460nm	0.1552	0.1448	0.1401	0.1568	0.1469	0.1413	-0.0018	-0.0023	-0.0012
470nm	0.1699	0.1582	0.1539	0.1718	0.1609	0.1554	-0.0019	-0.0027	-0.0015
480nm	0.1881	0.1749	0.1714	0.1905	0.1781	0.1735	-0.0024	-0.0032	-0.0021
490nm	0.2086	0.1931	0.1905	0.2119	0.1971	0.1934	-0.0033	-0.0040	-0.0029
500nm	0.2301	0.2120	0.2108	0.2344	0.2170	0.2148	-0.0043	-0.0050	-0.0040
510nm	0.2447	0.2244	0.2249	0.2498	0.2303	0.2299	-0.0051	-0.0059	-0.0050
520nm	0.2453	0.2248	0.2268	0.2509	0.2308	0.2322	-0.0058	-0.0062	-0.0056
530nm	0.2342	0.2147	0.2179	0.2398	0.2209	0.2236	-0.0056	-0.0062	-0.0057
540nm	0.2147	0.1975	0.2016	0.2200	0.2033	0.2070	-0.0053	-0.0058	-0.0054
550nm	0.1889	0.1745	0.1794	0.1935	0.1797	0.1843	-0.0046	-0.0052	-0.0049
560nm	0.1581	0.1461	0.1517	0.1622	0.1507	0.1562	-0.0041	-0.0046	-0.0045
570nm	0.1315	0.1220	0.1276	0.1350	0.1259	0.1315	-0.0035	-0.0039	-0.0039
580nm	0.1137	0.1057	0.1111	0.1157	0.1092	0.1145	-0.0030	-0.0035	-0.0034
590nm	0.1037	0.0965	0.1017	0.1065	0.0997	0.1048	-0.0028	-0.0032	-0.0031
600nm	0.0941	0.0876	0.0925	0.0965	0.0905	0.0954	-0.0024	-0.0029	-0.0029
610nm	0.0888	0.0828	0.0874	0.0911	0.0855	0.0902	-0.0023	-0.0027	-0.0028
620nm	0.0885	0.0828	0.0873	0.0909	0.0854	0.0900	-0.0024	-0.0028	-0.0027
630nm	0.0875	0.0817	0.0862	0.0898	0.0842	0.0889	-0.0023	-0.0025	-0.0027
640nm	0.0881	0.0823	0.0868	0.0903	0.0848	0.0894	-0.0022	-0.0025	-0.0026
650nm	0.0917	0.0858	0.0902	0.0941	0.0883	0.0929	-0.0024	-0.0027	-0.0027
660nm	0.0984	0.0917	0.0964	0.1009	0.0948	0.0994	-0.0025	-0.0029	-0.0030
670nm	0.0973	0.0907	0.0954	0.0999	0.0936	0.0983	-0.0026	-0.0029	-0.0029
680nm	0.0962	0.0897	0.0943	0.0988	0.0925	0.0972	-0.0028	-0.0028	-0.0029
690nm	0.0892	0.0834	0.0877	0.0915	0.0860	0.0903	-0.0023	-0.0026	-0.0026
700nm	0.0821	0.0770	0.0810	0.0842	0.0794	0.0833	-0.0021	-0.0024	-0.0023

(Case II; casewhere nondispersion-processed coloring agent is used)

According to the same manner as that of the above Case I except that a non-dispersion-processed pigment was used in place

of a dispersion-processed DA type coloring agent for PVC, samples were obtained and spectral reflectances were obtained similarly. The content is the content used in Table 1 multiplied by a pigment rate of DA color. In addition, database for CCM simulation is database for DA color divided by a pigment rate for each color. The differences $\Delta R-n$ between actually measured reflectance RST-n and CCM simulated reflectance RPR-n for a toning sample for the formulation is shown in Table 3. In addition, the difference curves of spectral reflectance regarding to $\Delta R-n$ in Table 3 is shown in Fig. 5, and the difference curves of spectral reflectance regarding to $(\Delta R2-\Delta R1)$ and $(\Delta R3-\Delta R1)$ are shown in Fig. 5. Fig. 5 is to be compared with Fig. 3, and Fig. 6 to be compared with Fig. 4.

Table 3

	RST-1	RST-2	RST-3	RPR-1	RPR-2	RPR-3	$\Delta R-1$	$\Delta R-2$	$\Delta R-3$
400nm	0.1355	0.1308	0.1338	0.1383	0.1302	0.1257	-0.0028	0.0006	0.0081
410nm	0.1337	0.1285	0.1315	0.1363	0.1282	0.1233	-0.0026	0.0003	0.0082
420nm	0.1319	0.1262	0.1292	0.1342	0.1262	0.1209	-0.0023	0.0000	0.0083
430nm	0.1319	0.1250	0.1290	0.1342	0.1261	0.1208	-0.0023	-0.0001	0.0082
440nm	0.1361	0.1298	0.1330	0.1385	0.1299	0.1245	-0.0024	-0.0001	0.0085
450nm	0.1419	0.1356	0.1389	0.1446	0.1357	0.1301	-0.0027	-0.0001	0.0088
460nm	0.1536	0.1472	0.1508	0.1568	0.1469	0.1413	-0.0032	0.0003	0.0095
470nm	0.1680	0.1618	0.1658	0.1718	0.1609	0.1554	-0.0038	0.0009	0.0104
480nm	0.1858	0.1799	0.1842	0.1905	0.1781	0.1735	-0.0049	0.0018	0.0107
490nm	0.2053	0.2004	0.2053	0.2119	0.1971	0.1934	-0.0068	0.0033	0.0119
500nm	0.2258	0.2224	0.2279	0.2344	0.2170	0.2148	-0.0088	0.0054	0.0131
510nm	0.2393	0.2380	0.2441	0.2498	0.2303	0.2299	-0.0105	0.0077	0.0142
520nm	0.2392	0.2403	0.2466	0.2509	0.2308	0.2322	-0.0117	0.0095	0.0144
530nm	0.2278	0.2318	0.2378	0.2398	0.2209	0.2238	-0.0120	0.0107	0.0140
540nm	0.2084	0.2147	0.2203	0.2200	0.2033	0.2070	-0.0116	0.0114	0.0133
550nm	0.1828	0.1914	0.1963	0.1935	0.1797	0.1843	-0.0107	0.0117	0.0120
560nm	0.1521	0.1630	0.1672	0.1622	0.1507	0.1562	-0.0101	0.0123	0.0110
570nm	0.1262	0.1375	0.1411	0.1350	0.1259	0.1315	-0.0088	0.0116	0.0096
580nm	0.1090	0.1199	0.1231	0.1187	0.1092	0.1145	-0.0077	0.0107	0.0088
590nm	0.0993	0.1098	0.1127	0.1065	0.0997	0.1048	-0.0072	0.0101	0.0079
600nm	0.0899	0.1000	0.1027	0.0965	0.0905	0.0954	-0.0066	0.0095	0.0073
610nm	0.0849	0.0946	0.0971	0.0911	0.0855	0.0902	-0.0062	0.0091	0.0069
620nm	0.0847	0.0943	0.0967	0.0909	0.0854	0.0900	-0.0062	0.0089	0.0067
630nm	0.0837	0.0932	0.0956	0.0898	0.0842	0.0889	-0.0061	0.0090	0.0067
640nm	0.0843	0.0937	0.0961	0.0903	0.0848	0.0894	-0.0060	0.0089	0.0067
650nm	0.0878	0.0974	0.0999	0.0941	0.0883	0.0929	-0.0063	0.0091	0.0070
660nm	0.0943	0.1041	0.1068	0.1009	0.0948	0.0994	-0.0066	0.0095	0.0074
670nm	0.0932	0.1030	0.1057	0.0999	0.0936	0.0983	-0.0067	0.0094	0.0074
680nm	0.0921	0.1018	0.1045	0.0988	0.0925	0.0972	-0.0067	0.0093	0.0073
690nm	0.0855	0.0946	0.0971	0.0915	0.0860	0.0903	-0.0060	0.0086	0.0068
700nm	0.0788	0.0874	0.0897	0.0842	0.0794	0.0833	-0.0054	0.0080	0.0064

When Fig. 3 and Fig. 5 are compared, a coincidental degree between curves shown in Fig. 3 is apparently better than that shown in Fig. 5. When Fig. 4 and Fig. 6 are compared, similarly, a magnitude of the difference shown in Fig. 6 is apparently greater than that shown in Fig. 4. This shows that the developing reproducibility is worse due to the use of non-dispersion-processed coloring agent in Fig. 5 and Fig. 6. That is, the deterioration of the reproducibility caused by

unsuitable coloring agent in the coloring process is recognized.

(Method for evaluation based on $L^*a^*b^*$ color specification value and its difference)

$L^*a^*b^*$ color specification value and its difference calculated from actually measured reflectance RST-n and simulated reflectance RPR-n in Table 2 are shown in Table 4. In addition, $L^*a^*b^*$ color specification value and its difference calculated from actually measured reflectance RST-n and simulated reflectance RPR-n in Table 3 are shown in Table 5. A method for measuring a color specification value was according to JIS Z 8722 'Method of color measurement. $L^*a^*b^*$ values are in D65 illuminant and 10 degree visual field.

Table 4

	RST-1	RST-2	RST-3	RPR-1	RPR-2	RPR-3		ΔR_1	ΔR_2	ΔR_3
L^*	48.01	46.33	46.75	48.49	46.91	47.28	ΔL^*	-0.48	-0.58	-0.53
a^*	-24.62	-23.50	-23.19	-24.86	-23.75	-23.40	Δa^*	0.24	0.25	0.21
b^*	3.06	2.67	4.42	3.51	3.11	4.99	Δb^*	-0.45	-0.44	-0.57

Table 5

	RST-1	RST-2	RST-3	RPR-1	RPR-2	RPR-3		ΔR_1	ΔR_2	ΔR_3
L^*	47.37	48.11	48.65	48.49	46.91	47.28	ΔL^*	-1.12	-1.20	1.37
a^*	-24.60	-23.38	-23.58	-24.86	-23.75	-23.40	Δa^*	0.26	0.37	-0.18
b^*	2.36	5.02	5.11	3.51	3.11	4.99	Δb^*	-1.15	1.91	0.12

When ΔR_1 , ΔR_2 and ΔR_3 in Table 4 and Table 5 are compared, it can be seen that values are generally greater in Table 5. This shows that the developing reproducibility is worse due to the use of a non-dispersion-processed pigment. That is, the deterioration of the reproducibility caused by unsuitable coloring agent in a coloring process is recognized.

(Method for evaluation based on difference of difference of $L^*a^*b^*$)

The difference between ΔR_1 , ΔR_2 and ΔR_3 in Table 4 using ΔR_1 as a standard and the color difference calculated from the difference are shown in Table 6. The difference between ΔR_1 , ΔR_2 and ΔR_3 in Table 5 using ΔR_1 as a standard and the color difference calculated from the difference are shown in Table 7.

Table 6

	① ΔR_1	② ΔR_2	③ ΔR_3	Difference ②-①	Difference ③-①
ΔL^*	-0.48	-0.58	-0.53	-0.10	-0.05
Δa^*	0.24	0.25	0.21	0.01	-0.03
Δb^*	-0.45	-0.44	-0.57	0.01	-0.12
Color difference				0.10	0.13

Table 7

	① ΔR_1	② ΔR_2	③ ΔR_3	Difference ②-①	Difference ③-①
ΔL^*	-1.12	1.20	1.37	2.32	2.49
Δa^*	0.26	0.37	-0.18	0.11	-0.44
Δb^*	-1.15	1.91	0.12	3.06	1.27
Color difference				3.84	2.83

When color difference in Table 6 and Table 7 are compared, it can be seen that color difference in Table 7 is greater. This shows that the developing reproducibility is worse due to the use of a non-dispersion-processed pigment. That is, the deterioration of the reproducibility caused by unsuitable coloring agent in the coloring process is recognized.

(Method for evaluation based on statistical treatment results of difference of $L^*a^*b^*$ color specification value)

The difference of $L^*a^*b^*$ color specification value calculated from actually measured reflectance RST-n and simulated reflectance RPR-n is statistically treated, it is easier to determine comprehensively. Standard deviation is suitable in the case where data are large such as correction toning of lot product in production section. In addition, when data are small in such case as new color toning, (maximum-minimum) and an average are suitable. Herein, an example using (maximum-minimum) and an average is shown as an example of new

color toning in Table 8 and 9. Table 8 and Table 9 show (maximum-minimum) of ΔR -n in Table 4 and Table 5 and difference between ΔR -ns and its average, respectively, and show color difference calculated from those values.

Table 8

	① ΔR_1	② ΔR_2	③ ΔR_3	Maximum-minimum
ΔL^*	-0.48	-0.58	-0.53	0.10
Δa^*	0.24	0.25	0.21	0.04
Δb^*	-0.45	-0.44	-0.57	0.13
			Color difference	0.17

	④ difference ①-②	⑤ difference ②-③	⑥ difference ③-①	Average of ④, ⑤ and ⑥
ΔL^*	0.10	0.05	0.05	0.07
Δa^*	0.01	0.04	0.03	0.03
Δb^*	0.01	0.13	0.12	0.09
色差	0.10	0.14	0.13	0.11

Table 9

	① ΔR_1	② ΔR_2	③ ΔR_3	Maximum-minimum
ΔL^*	-1.12	1.20	1.37	2.49
Δa^*	0.26	0.37	-0.18	0.55
Δb^*	-1.15	1.91	0.12	3.06
			Color difference	3.98
	④ difference ①-②	⑤ difference ②-③	⑥ difference ③-①	Average of ④, ⑤ and ⑥
ΔL^*	2.32	0.17	2.49	1.66
Δa^*	0.11	0.55	0.44	0.37
Δb^*	3.06	1.79	1.27	2.04
色差	3.84	1.88	2.83	2.66

The color differences in Table 8 and Table 9 are the reproducibility in the case of comprehensive determination. The color difference in Table 9 where a non-dispersion-processed pigment is used is remarkably greater than that in Table 8 where a dispersion-processed coloring agent is used. That is, the deterioration of the reproducibility caused by unsuitable coloring agent in a coloring process is recognized.

(CCM screen display)

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In addition, in Fig. 8, a square part of an ordinate shows (maximum-minimum) of ΔL^* (lightness) in Table 9, that is, the reproducibility, and elliptical double lines show (maximum-minimum) of Δa^* and Δb^* in Table 9, that is, the reproducibility. In addition, B point shows color difference between the last time product (immediate prior product) and the target color in a toning sample producing process.

From Fig. 8, it is determined that since the last time product is inside a range of the reproducibility of ΔL^* indicating Light-Dark, it is impossible to further correct and tonings should be stopped.

Example 2

(Case 3: method for testing an abnormal sample product in a toning process in reproducibility evaluation)

A sample group A was produced at the formulating rate (unit is 'gram') shown in Table 10 using dispersion-processed DA color having the excellent developing reproducibility, which was used in the aforementioned Case I. That is, the sample formulation was determined by CCM simulation so that ΔE^* is changed by 2 degrees by change of one of three attributes hue (H+), lightness (V+) and chroma (C+) relative to a standard, and an abnormal sample product was produced by adding a heterogeneous coloring agent to a standard product to change ΔE^* by around 1 to obtain the abnormal sample formulation b. The sample producing procedure was the same as in Case I.

Table 10

	A-standard	A-H+	A-V+	A-C+	A-b
PVC resin compound	50	50	50	50	50
EP-4050 (White)	0.8485	0.8422	0.8672	0.8379	0.8485
P-4710(1/10)(Black)	0.0540	0.0568	0.0471	0.0499	0.0540
P-4172 (Red)	0.0257	0.0218	0.0224	0.0289	0.0257
P-4420 (Yellow)	0.0718	0.0792	0.0633	0.0833	0.0718
P-4510 (Green)	—	—	—	—	0.0050

Here, it is on the assumption that, in trying to produce a standard, samples H+, V+ and C+, a standard was erroneously produced according to the formulation b. The results of these actually measured reflectance RST-n and simulated reflectance RPR-n, the difference $\Delta R-n$ between both reflectances and $\Delta R-ave$ except for A-b sample are shown in Table 11 and Fig. 9. In the case of the b sample, A-b sample was used in measurement of actually measured reflectance RST-b, and A-standard formulation was used in simulation of simulated reflectance RPR-b by CCMS system. In addition, the color specification value, the difference of color specification value and the color difference calculated from actually measured reflectance RST-n and simulated reflectance RPR-n are shown in Table 12, respectively. In Table 12, $L^*a^*b^*$ values are in D65 illuminant and 10 degree visual field.

Table 11

Wavelength	RST(A-H+)	RPR(A-H+)	RST(A-V+)	RPR(A-V+)	RST(A-H+)	RPR(A-H+)	RST(A-C+)	RPR(A-C+)	RST(A-b)	RPR	$\Delta R(A-H+)$	$\Delta R(A-V+)$	$\Delta R(A-C+)$	$\Delta R(A-b)$	$\Delta R\text{-ave}$
380nm	0.0806	0.0823	0.0869	0.0886	0.0807	0.0816	0.0804	0.0804	0.0804	0.0838	-0.0017	-0.0017	-0.0017	-0.0014	-0.0014
390nm	0.1098	0.1126	0.1260	0.1280	0.1091	0.1121	0.1124	0.1164	0.1164	0.1164	-0.0030	-0.0042	-0.0050	-0.0040	-0.0034
400nm	0.1380	0.1432	0.1566	0.1633	0.1375	0.1425	0.1443	0.1490	0.1490	0.1490	-0.0042	-0.0067	-0.0090	-0.0060	-0.0053
410nm	0.1366	0.1409	0.1542	0.1614	0.1345	0.1398	0.1421	0.1468	0.1468	0.1468	-0.0043	-0.0072	-0.0053	-0.0047	-0.0056
420nm	0.1342	0.1385	0.1518	0.1595	0.1314	0.1370	0.1399	0.1445	0.1445	0.1445	-0.0043	-0.0077	-0.0056	-0.0046	-0.0059
430nm	0.1317	0.1373	0.1489	0.1581	0.1293	0.1356	0.1389	0.1432	0.1432	0.1432	-0.0056	-0.0092	-0.0063	-0.0053	-0.0070
440nm	0.1321	0.1387	0.1495	0.1593	0.1292	0.1369	0.1375	0.1443	0.1443	0.1443	-0.0066	-0.0098	-0.0067	-0.0058	-0.0080
450nm	0.1352	0.1416	0.1520	0.1618	0.1324	0.1396	0.1397	0.1467	0.1467	0.1467	-0.0064	-0.0098	-0.0072	-0.0070	-0.0078
460nm	0.1404	0.1483	0.1569	0.1678	0.1368	0.1459	0.1439	0.1486	0.1486	0.1486	-0.0063	-0.0106	-0.0091	-0.0067	-0.0093
470nm	0.1454	0.1547	0.1626	0.1734	0.1424	0.1516	0.1486	0.1537	0.1537	0.1537	-0.0063	-0.0106	-0.0099	-0.0068	-0.0099
480nm	0.1557	0.1620	0.1686	0.1792	0.1504	0.1596	0.1562	0.1614	0.1614	0.1614	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
490nm	0.1580	0.1682	0.1739	0.1841	0.1534	0.1632	0.1595	0.1649	0.1649	0.1649	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
500nm	0.1640	0.1721	0.1776	0.1882	0.1597	0.1697	0.1657	0.1714	0.1714	0.1714	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
510nm	0.1647	0.1721	0.1776	0.1882	0.1597	0.1697	0.1657	0.1714	0.1714	0.1714	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
520nm	0.1670	0.1738	0.1791	0.1890	0.1629	0.1729	0.1689	0.1746	0.1746	0.1746	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
530nm	0.1733	0.1790	0.1859	0.1919	0.1694	0.1794	0.1654	0.1711	0.1711	0.1711	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
540nm	0.1746	0.1799	0.1877	0.1930	0.1666	0.1728	0.1626	0.1683	0.1683	0.1683	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
550nm	0.1734	0.1787	0.1860	0.1916	0.1651	0.1715	0.1611	0.1668	0.1668	0.1668	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
560nm	0.1810	0.1854	0.1951	0.1997	0.1745	0.1800	0.1705	0.1762	0.1762	0.1762	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
570nm	0.2018	0.2053	0.2202	0.2236	0.2010	0.2056	0.2003	0.2049	0.2049	0.2049	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
580nm	0.2220	0.2243	0.2453	0.2478	0.2290	0.2323	0.2234	0.2277	0.2277	0.2277	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
590nm	0.2312	0.2339	0.2576	0.2605	0.2435	0.2470	0.2333	0.2397	0.2397	0.2397	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
600nm	0.2357	0.2363	0.2633	0.2644	0.2504	0.2517	0.2385	0.2433	0.2433	0.2433	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
610nm	0.2368	0.2370	0.2648	0.2666	0.2521	0.2532	0.2397	0.2445	0.2445	0.2445	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
620nm	0.2363	0.2371	0.2644	0.2667	0.2524	0.2536	0.2397	0.2445	0.2445	0.2445	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
630nm	0.2354	0.2361	0.2633	0.2644	0.2514	0.2526	0.2397	0.2445	0.2445	0.2445	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
640nm	0.2336	0.2350	0.2618	0.2638	0.2497	0.2515	0.2397	0.2445	0.2445	0.2445	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
650nm	0.2325	0.2331	0.2604	0.2618	0.2484	0.2496	0.2397	0.2445	0.2445	0.2445	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
660nm	0.2332	0.2325	0.2610	0.2610	0.2490	0.2489	0.2323	0.2390	0.2390	0.2390	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
670nm	0.2329	0.2314	0.2607	0.2601	0.2486	0.2478	0.2323	0.2390	0.2390	0.2390	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
680nm	0.2326	0.2303	0.2603	0.2588	0.2482	0.2466	0.2323	0.2390	0.2390	0.2390	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
690nm	0.2307	0.2289	0.2582	0.2574	0.2462	0.2452	0.2323	0.2390	0.2390	0.2390	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097
700nm	0.2287	0.2275	0.2560	0.2559	0.2441	0.2437	0.2311	0.2350	0.2350	0.2350	-0.0062	-0.0102	-0.0098	-0.0064	-0.0097

Table 12

D65/10°	No.	Sample Name	L*	a*	b*	ΔL^*	Δa^*	Δb^*	ΔE^*
	1	RST(A-ave)	51.31	7.19	11.24	-0.58	0.74	0.96	1.34
	2	RPR(A-ave+)	51.89	6.45	10.28				
	1	RST(A-H+)	50.67	5.71	11.16	-0.54	0.79	0.77	1.23
	2	RPR(A-H+)	51.21	4.92	10.39				
	3	RST(A-V+)	52.69	7.21	10.68	-0.56	0.58	1.25	1.49
	4	RPR(A-V+)	53.25	6.63	9.43				
	5	RST(A-C+)	50.58	8.66	11.87	-0.64	0.86	0.85	1.37
	6	RPR(A-C+)	51.22	7.80	11.02				
	7	RST(A-b)	50.42	6.67	9.83	-0.80	0.04	0.42	0.90
	8	RPR(A-std)	51.22	6.63	9.41				
						$\Delta(\Delta L^*)$	$\Delta(\Delta a^*)$	$\Delta(\Delta b^*)$	$\Delta(\Delta E^*)$
						-0.58	0.74	0.96	1.34
						-0.54	0.79	0.77	1.23
						-0.56	0.58	1.25	1.49
						-0.64	0.86	0.85	1.37
						-0.80	0.04	0.42	0.90

As apparent from Table 11, Table 12 and Fig. 9, $\Delta R(A-b)$ shows the abnormal value as compared with $\Delta R(A-H+)$, $\Delta R(A-V+)$ and $\Delta R(A-C+)$, and sample b can be extracted as an abnormal product. In Table 12, the designated value '2.0' of ΔE^* includes simulation error, resulting in '1.23', '1.49' and '1.37' but they are close and, similarly, the designated value '1.0' of ΔE^* resulted in '0.9'. Then, provisional true RST'-b was obtained, and $\Delta R'$ -b and $\Delta R''$ -b were calculated. The results are shown in Table 13 and Fig. 10. In addition, in order to obtain the relationship between ΔR -actual sample, the standard formulation was produced according to the correct method, and its actually measured reflectance RST-standard was measured. The results are shown in Table 13 and Fig. 10, together

with actually measured RST-b. The relationship between Δ
R-actual sample refers to the difference between RST-standard
and actually measured RST-b.

Table 13

Wavelength	RST-b	RST-b	ΔR -b	ΔR -b	ΔR -b	RST-std	ΔR -actual	ΔR -b
380nm	0.0824	0.0804	0.0020	0.0020	0.0003	0.0807	0.0003	-0.0034
390nm	0.1130	0.1124	0.0006	0.0006	0.0005	0.1129	0.0005	-0.0040
400nm	0.1437	0.1443	-0.0006	-0.0006	0.0008	0.1451	0.0008	-0.0047
410nm	0.1412	0.1421	-0.0009	-0.0009	0.0007	0.1428	0.0007	-0.0047
420nm	0.1386	0.1399	-0.0013	-0.0013	0.0005	0.1404	0.0005	-0.0046
430nm	0.1362	0.1369	-0.0007	-0.0007	0.0004	0.1373	0.0004	-0.0063
440nm	0.1363	0.1375	-0.0012	-0.0012	0.0003	0.1378	0.0003	-0.0068
450nm	0.1389	0.1397	-0.0008	-0.0008	0.0003	0.1400	0.0003	-0.0070
460nm	0.1433	0.1439	-0.0006	-0.0006	0.0002	0.1441	0.0002	-0.0087
470nm	0.1484	0.1486	-0.0002	-0.0002	0.0001	0.1487	0.0001	-0.0092
480nm	0.1536	0.1537	-0.0001	-0.0001	0.0001	0.1538	0.0001	-0.0098
490nm	0.1582	0.1585	-0.0003	-0.0003	0.0000	0.1585	0.0000	-0.0094
500nm	0.1612	0.1614	-0.0002	-0.0002	0.0000	0.1614	0.0000	-0.0084
510nm	0.1604	0.1602	0.0002	0.0002	0.0001	0.1603	0.0001	-0.0080
520nm	0.1622	0.1620	0.0002	0.0002	0.0001	0.1621	0.0001	-0.0074
530nm	0.1687	0.1686	0.0001	0.0001	0.0001	0.1687	0.0001	-0.0062
540nm	0.1702	0.1700	0.0002	0.0002	0.0002	0.1702	0.0002	-0.0058
550nm	0.1688	0.1685	0.0003	0.0003	0.0004	0.1689	0.0004	-0.0061
560nm	0.1774	0.1768	0.0006	0.0006	0.0006	0.1774	0.0006	-0.0054
570nm	0.2011	0.2003	0.0008	0.0008	0.0011	0.2014	0.0011	-0.0046
580nm	0.2250	0.2234	0.0016	0.0016	0.0022	0.2256	0.0022	-0.0043
590nm	0.2367	0.2333	0.0034	0.0034	0.0040	0.2373	0.0040	-0.0064
600nm	0.2423	0.2365	0.0058	0.0058	0.0065	0.2430	0.0065	-0.0068
610nm	0.2437	0.2357	0.0080	0.0080	0.0086	0.2443	0.0086	-0.0087
620nm	0.2434	0.2345	0.0089	0.0089	0.0096	0.2441	0.0096	-0.0100
630nm	0.2425	0.2329	0.0096	0.0096	0.0101	0.2430	0.0101	-0.0107
640nm	0.2408	0.2309	0.0099	0.0099	0.0105	0.2414	0.0105	-0.0116
650nm	0.2395	0.2295	0.0100	0.0100	0.0105	0.2400	0.0105	-0.0111
660nm	0.2402	0.2312	0.0090	0.0090	0.0096	0.2408	0.0096	-0.0088
670nm	0.2400	0.2323	0.0077	0.0077	0.0082	0.2405	0.0082	-0.0057
680nm	0.2397	0.2335	0.0062	0.0062	0.0067	0.2402	0.0067	-0.0044
690nm	0.2377	0.2323	0.0054	0.0054	0.0060	0.2383	0.0060	-0.0042
700nm	0.2356	0.2311	0.0045	0.0045	0.0052	0.2363	0.0052	-0.0039

As apparent from Table 13 and Fig. 10, $\Delta R' -b$ and $\Delta R' '$ $-b$ obtained by calculation are extremely coincident with the ΔR -actual, and it was confirmed that the use of $\Delta R' -b$ and $\Delta R' '$ $-b$ as a simulated value is effective. The previous method when CCM is applied to evaluation of the reproducibility of the known formulation sample compared actually measured reflectance RST of the sample and simulated reflectance RPR calculated from the known formulation for the sample and determined abnormal when its difference ΔR is too great. That is, since the previous method was an evaluation method in which evaluation was performed on individual samples, when a reproductive error was small, it was negligible as compared with simulation error and, thus, abnormality could not be detected. However, according to the present method, evaluation is performed between respective samples and, thus, an abnormal sample in the case of small error can be also detected. That is, it can be seen that $\Delta R-b$ obtained by the previous method ($\Delta R(A-b)$ in the figure) is remarkably remote from the actually measured ΔR -actual.

Then, in order to presume from which coloring agent the error factor of an abnormal product b is derived, the reflectance of a target was set to be $(RST-b - \Delta R-ave)$, CCM database with 20 kinds of coloring agent registered therein was used, those having the high coincidental rate of spectral reflectance with that of a target sample was selected, RPR-m thereof was simulated,

and the difference $\Delta R' - m$ to RPR-b calculated from the regular formulation, more particularly, $\Delta R' -1$, $\Delta R' -2$, $\Delta R' -3$, $\Delta R' -4$, $\Delta R' -5$ were obtained. The results thereof and the difference between $\Delta R' -m$ and $\Delta R' -b$ are shown in Table 14 and Fig. 11. Here, m indicates the number of the selected formulation.

Table 11

Wavelength	RST(A-H _z)	RPRA(A-H _z)	RST(A-V _z)	RPRA(V _z)	RST(A-V _z)	RPRA(V _z)	RST(A-C _z)	RPRA(C _z)	RST(A-C _z)	RPRA(C _z)	RPR (A-std)	ΔR(A-H _z)	ΔR(A-V _z)	ΔR(A-C _z)	ΔR(A-H _z)	ΔR(A-V _z)	ΔR(A-C _z)	ΔR-ave
380nm	0.0806	0.0869	0.0869	0.0886	0.0886	0.0886	0.0816	0.0816	0.0804	0.0804	0.0804	-0.0017	-0.0017	-0.0009	-0.0034	-0.0014	-0.0034	-0.0014
390nm	0.1098	0.1128	0.1128	0.1260	0.1260	0.1260	0.1091	0.1121	0.1164	0.1164	0.1164	-0.0030	-0.0042	-0.0030	-0.0040	-0.0034	-0.0040	-0.0034
400nm	0.1390	0.1432	0.1432	0.1566	0.1566	0.1566	0.1375	0.1425	0.1443	0.1443	0.1443	-0.0042	-0.0067	-0.0042	-0.0050	-0.0047	-0.0050	-0.0047
410nm	0.1366	0.1409	0.1409	0.1542	0.1542	0.1542	0.1345	0.1398	0.1421	0.1421	0.1421	-0.0043	-0.0072	-0.0043	-0.0051	-0.0047	-0.0051	-0.0047
420nm	0.1342	0.1385	0.1385	0.1518	0.1518	0.1518	0.1314	0.1370	0.1399	0.1399	0.1399	-0.0043	-0.0077	-0.0043	-0.0056	-0.0046	-0.0056	-0.0046
430nm	0.1317	0.1373	0.1373	0.1489	0.1489	0.1489	0.1293	0.1356	0.1389	0.1389	0.1389	-0.0056	-0.0092	-0.0056	-0.0063	-0.0059	-0.0063	-0.0059
440nm	0.1321	0.1387	0.1387	0.1495	0.1495	0.1495	0.1292	0.1359	0.1375	0.1375	0.1375	-0.0056	-0.0098	-0.0056	-0.0063	-0.0060	-0.0063	-0.0060
450nm	0.1352	0.1416	0.1416	0.1520	0.1520	0.1520	0.1324	0.1396	0.1397	0.1397	0.1397	-0.0064	-0.0098	-0.0064	-0.0072	-0.0070	-0.0072	-0.0070
460nm	0.1404	0.1483	0.1483	0.1569	0.1569	0.1569	0.1368	0.1459	0.1439	0.1439	0.1439	-0.0079	-0.0110	-0.0079	-0.0091	-0.0097	-0.0091	-0.0097
470nm	0.1484	0.1547	0.1547	0.1626	0.1626	0.1626	0.1424	0.1516	0.1486	0.1486	0.1486	-0.0093	-0.0108	-0.0093	-0.0092	-0.0092	-0.0092	-0.0092
480nm	0.1527	0.1620	0.1620	0.1696	0.1696	0.1696	0.1460	0.1579	0.1537	0.1537	0.1537	-0.0093	-0.0106	-0.0093	-0.0098	-0.0098	-0.0098	-0.0098
490nm	0.1590	0.1682	0.1682	0.1739	0.1739	0.1739	0.1534	0.1652	0.1595	0.1595	0.1595	-0.0092	-0.0102	-0.0092	-0.0098	-0.0094	-0.0098	-0.0094
500nm	0.1640	0.1721	0.1721	0.1776	0.1776	0.1776	0.1567	0.1687	0.1614	0.1614	0.1614	-0.0086	-0.0086	-0.0086	-0.0090	-0.0084	-0.0090	-0.0086
510nm	0.1647	0.1721	0.1721	0.1776	0.1776	0.1776	0.1559	0.1682	0.1602	0.1602	0.1602	-0.0074	-0.0077	-0.0074	-0.0078	-0.0078	-0.0078	-0.0078
520nm	0.1670	0.1738	0.1738	0.1791	0.1791	0.1791	0.1578	0.1696	0.1620	0.1620	0.1620	-0.0068	-0.0068	-0.0068	-0.0067	-0.0067	-0.0067	-0.0067
530nm	0.1733	0.1780	0.1780	0.1859	0.1859	0.1859	0.1649	0.1778	0.1700	0.1700	0.1700	-0.0057	-0.0060	-0.0057	-0.0053	-0.0053	-0.0053	-0.0053
540nm	0.1746	0.1789	0.1789	0.1877	0.1877	0.1877	0.1666	0.1778	0.1700	0.1700	0.1700	-0.0053	-0.0053	-0.0053	-0.0053	-0.0053	-0.0053	-0.0053
550nm	0.1734	0.1787	0.1787	0.1860	0.1860	0.1860	0.1651	0.1715	0.1700	0.1700	0.1700	-0.0044	-0.0046	-0.0044	-0.0044	-0.0044	-0.0044	-0.0044
560nm	0.1810	0.1854	0.1854	0.1951	0.1951	0.1951	0.1745	0.1800	0.1768	0.1768	0.1768	-0.0035	-0.0034	-0.0035	-0.0035	-0.0034	-0.0035	-0.0034
570nm	0.2018	0.2053	0.2053	0.2202	0.2202	0.2202	0.2010	0.2056	0.2003	0.2003	0.2003	-0.0023	-0.0023	-0.0023	-0.0023	-0.0023	-0.0023	-0.0023
580nm	0.2220	0.2243	0.2243	0.2478	0.2478	0.2478	0.2290	0.2323	0.2234	0.2234	0.2234	-0.0023	-0.0023	-0.0023	-0.0023	-0.0023	-0.0023	-0.0023
590nm	0.2312	0.2339	0.2339	0.2576	0.2576	0.2576	0.2435	0.2470	0.2333	0.2333	0.2333	-0.0023	-0.0023	-0.0023	-0.0023	-0.0023	-0.0023	-0.0023
600nm	0.2367	0.2393	0.2393	0.2633	0.2633	0.2633	0.2504	0.2517	0.2365	0.2365	0.2365	-0.0011	-0.0011	-0.0011	-0.0011	-0.0011	-0.0011	-0.0011
610nm	0.2368	0.2370	0.2370	0.2648	0.2648	0.2648	0.2521	0.2532	0.2357	0.2357	0.2357	-0.0008	-0.0008	-0.0008	-0.0008	-0.0008	-0.0008	-0.0008
620nm	0.2363	0.2371	0.2371	0.2644	0.2644	0.2644	0.2524	0.2536	0.2345	0.2345	0.2345	-0.0008	-0.0013	-0.0008	-0.0013	-0.0012	-0.0010	-0.0011
630nm	0.2354	0.2361	0.2361	0.2633	0.2633	0.2633	0.2514	0.2526	0.2329	0.2329	0.2329	-0.0007	-0.0015	-0.0007	-0.0015	-0.0012	-0.0010	-0.0011
640nm	0.2356	0.2350	0.2350	0.2618	0.2618	0.2618	0.2497	0.2515	0.2309	0.2309	0.2309	-0.0014	-0.0020	-0.0014	-0.0020	-0.0016	-0.0016	-0.0017
650nm	0.2325	0.2323	0.2323	0.2604	0.2604	0.2604	0.2484	0.2496	0.2295	0.2295	0.2295	-0.0014	-0.0014	-0.0014	-0.0014	-0.0014	-0.0014	-0.0014
660nm	0.2332	0.2325	0.2325	0.2610	0.2610	0.2610	0.2490	0.2489	0.2312	0.2312	0.2312	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007
670nm	0.2329	0.2314	0.2314	0.2607	0.2607	0.2607	0.2486	0.2478	0.2290	0.2290	0.2290	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007
680nm	0.2326	0.2303	0.2303	0.2603	0.2603	0.2603	0.2482	0.2466	0.2235	0.2235	0.2235	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007
690nm	0.2307	0.2329	0.2329	0.2582	0.2582	0.2582	0.2452	0.2452	0.2235	0.2235	0.2235	-0.0011	-0.0011	-0.0011	-0.0011	-0.0011	-0.0011	-0.0011
700nm	0.2287	0.2273	0.2273	0.2560	0.2560	0.2560	0.2441	0.2437	0.2211	0.2211	0.2211	-0.0012	-0.0012	-0.0012	-0.0012	-0.0012	-0.0012	-0.0012

As apparent from Fig. 11, it can be seen that $\Delta R' -1$ is the most coincidental with $\Delta R' -b$. In addition, the formulation of $\Delta R' -1$ is shown in Table 15 (in Table 15, the formulation of $\Delta R' -1$ indicates 'A-b/automatic'). As apparent from Table 15, it was confirmed that the calculated error rate is extremely coincidental with the actual error rate.

Table 15

	A-std	A-b	$\Delta R' -1$ A-b/auto	
PVC resin Compound	50.0000	50.0000	50.0000	Error rate
EP-4050 (White)	0.8485	0.8485	0.8481	-0.14%
P-4710 (Black)	0.0540	0.0540	0.0536	0.55%
P-4172 (Red)	0.0257	0.0257	0.0260	-1.36%
P-4420 (Yellow)	0.0718	0.0718	0.0703	1.90%
P-4510 (Green)	-	0.0020	0.0021	-5.20%
sum.	1.0000	1.0020	1.0001	

Comparative Example

A target was set at RST-b, CCM database with 20 kinds of coloring agents registered therein was used, 5 kinds having the high coincidental rate of spectral reflectance with that of a target sample were picked up, RPR-L thereof was calculated, and the difference $\Delta R' -L$ to RPR-b calculated from the regular formulation was obtained. Further, the difference between $\Delta R' -L$ and $\Delta R' -b$ was obtained. The results are shown in Fig. 12. As apparent from Fig. 12, it can be seen that $\Delta R' -1$ can not be specified as being the closest to $\Delta R' -b$, and is not remarkably different from $\Delta R' -2$, $\Delta R' -3$, $\Delta R' -4$ and $\Delta R' -5$.

Industrial applicability

According to the first invention, by displaying the actually measured color difference and the reproducibility for a sample produced in toning such as CCM toning and visual toning, it becomes possible to rapidly and simply determine whether toning work should be continued or not. According to the second invention, in the reproducibility evaluating method, an abnormal sample can be extracted and, at the same time, coloring agent for its error can be presumed and its amount can be presumed, leading to investigation of the abnormal cause.